International Journal for Quality Research 8(4) 557–568
ISSN 1800-6450

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Article info:
Received 30.09.2014
Accepted 26.11.2014

UDC – 54.061

DESIGN OF MANUAL MATERIAL HANDLING SYSTEM THROUGH COMPUTER AIDED ERGONOMICS: A CASE STUDY AT BDTSC TEXTILE FIRM

Abstract: *Designing of lifting, pushing and pulling activities based on the physical and physiological capabilities of the operators is essential. The purpose of this study is to analyze manual material handling (MMH) working posture of the operators using 3D Static Strength Prediction Program (3DSSPP) software and to identify major areas causing long last injury of operators. The research has investigated the fit between the demands of tasks and the capabilities of operators. At the existing situations, the actual capabilities of operators have been computed with the help of 3DSSPP software and compared with NIOSH standards. Accordingly, operators' working posture is at an unacceptable position that exposes them for musculoskeletal disorders. Then, after the improvement of the design of MMH device (cart's roller), the result showed that the forces required by the operators to push and pull the sliver cans have been reduced from 931.77 Newton to 194.23 Newton. Furthermore, improvement of MMH cart's roller has reduced the awkward posture of operators and the risk of musculoskeletal disorders. The improved manual material handling design also saves about 1828.40 ETB per month for the company.*

Keywords: *musculoskeletal injury, manual material handling, computer aided ergonomics, 3DSSPP*

1. Introduction[1]

Manual material handling is the moving of objects unaided by mechanical devices. Manual material handling includes activities like pushing, pulling, carrying, lifting, and lowering. A study at Purdue University in 2008, shows, "manual material handling is a leading cause of occupational injuries". The average cost of this type injury in manufacturing company, especially in textile industry is about $1,937".

Manual material handling (MMH) work contributes to a large percentage of cases of musculoskeletal disorders. Musculoskeletal disorders often involve strains and sprains to the lower back, shoulders, and upper limbs. It can result in protracted pain, disability, medical treatment, and financial stress, and employers often find themselves paying the bill, either directly or through workers' compensation insurance, at the same time they must cope with the loss of the full capacity of their workers. With the help of

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the 3D Static Strength Prediction Program (3DSSPP) software, manual material handling tasks can be designed and analyzed by considering different aspects of ergonomic principles to minimize all the musculoskeletal disorders.

The development of automation through extensive implementation of technology is one of the major trends in modern society. Computers are being used more frequently to improve the quality of different areas of ergonomics and safety. Computer-Aided production and design technology requires implementation of Computer-Aided Ergonomics methods. Computer-Aided Ergonomics Methods is the implementation of information technology in ergonomics and safety methods and the integration of those methods into design, production and decision making.

The major aim of this study is to analyze the MMH working posture of the operators using 3DSSPP software and to identify major areas causing long last injury of operators related to ergonomics and manual material handling system.

Computer-Aided Design (CAD) clearly offers new possibilities to integrate ergonomic knowledge into the design process. A wide variety of ergonomic topics are of relevance to the application of computer-aided design systems concerned with layout design, displays and controls, fields of vision, areas of movement, physical strength and working environment. Computer systems have been developed, for example, to analyze and to improve workplace structures, man-machine systems, production information systems and working methods. Any job that involves heavy labor or manual material handling may include a high risk for injury on the job. Manual material handling entails lifting, but also usually includes climbing, pushing, pulling, and pivoting, all of which pose the risk of injury to the back. MMH work contributes to a large percentage of cases of musculoskeletal disorders.

Back pain has many causes and it is often difficult and costly to pinpoint the factors responsible. One emerging theory states that most industrial back pain results from cumulative strains to the discs caused by repeated, stressful work, such as manual material handling. The underlying factors responsible for these strains take on much greater importance than trying to fix the one-shot incidents, and finding those factors needs to become a primary goal to reduce back injuries.

In textile manufacturing firms, manual material handling causes more than a quarter of the work-related injuries reported each year (OSHA, 2008). Based on this report, around 60% is an injury to the back, and most result in permanent disablement. Many injuries arise from stresses and strains over a period of time rather than from a single event. Therefore, using a systematic method of reviewing jobs for reducing material handling injuries usually pays dividends through increased productivity and a reduction in operating costs.

In BDTSC, it has observed that manual material handling system is very poor in such a way: handling systems are not properly designed; like carts for transporting full sliver cans. Those carts (manual material handling device) are conventional devices that require high energy and effort of the operators.

The general objective of the study is to minimize or eliminate the risk of operators' physical and physiological disorders through poor MMH system. The research has investigated the fit between the demands of tasks and the capabilities of the operators that would reduce operators' efforts by decreasing the demanded forces in lifting, handling, pushing, and pulling materials. Furthermore, the study has identified the risk factors and suggested the remedial action to avoid these factors for preventing injuries and musculoskeletal disorders.

2. Methodology

It is difficult to design the jobs exclusively for the needs of technology without considering the human or operator's physical, physiological and psychological capabilities. Especially, in designing of labor intensive tasks such as manual material handling requires the fitness of the physical capability of the operator and the amount of force required to perform the task. Otherwise, the operator would suffer and expose to trauma and injuries. Therefore, There is an all round demand for developing the operator's jobs which can satisfy thier needs. The jobs need to be excellent from the point of view of well being of the operator, productivity improvement and job satisfaction. The job should fit to the opeartor rather forcing human being to fit the job.

For the purpose of this research, the quality of work life can be described as the favorable working environment that supports and promotes satisfaction of operators by designing proper fitness between working posture of manual material handling and operators' physical capability. Hackman (1980) identified that the work environment that is able to fulfill employees' personal needs is considered to provide a positive interaction effect, which will lead to an excellent quality of work life.

The methodology used to conduct this research is basically on visualization of the manual material handling system tasks in BDTSC spinning section, interviewing the operators for their task experiences and musculoskeletal situations, clinical examination records that focus on the section operators used to describe the criticality of the injury.

The body measurement and posture of the operators have been taken into consideration and with the help of 3D SSPP ergonomic design software, the allowable design requirements have been considered. The purpose of using this software is to use easy and user friendly graphical interface and to analyze the quantitative ergonomic input parameters which has indicated safe limit of the work type.

The principles of National Institute for Occupational Safety and Health's (NIOSH) guidelines for Manual handling system (Revised NIOSH, 1981, 1994) has been considered as a reference to identify the impact of the injury.

3. Manual material handling system design

Manual material handling (MMH) involves the use of the human body to lift, lower, fill, empty, or carry loads. A variety of MMH techniques and tools exist to alleviate these potential problems. Most jobs require some handling, but about 10 percent require extensive manual materials handling (Stanton *et al.*, 2004). In BDTSC, the researchers have been observed that almost all workstations involve manual material handling system. Some of them are: baling operations and can transportation.

In this working area, surveys of information and data from the workers who have worked more than 20 years in the factory have been considered. The information and data has been collected from medical records of the factory from October, 2010 to December, 2013. Accordingly, the result has shown as follows:

- 19 Women operators has got back injury and related problems,
- 8 men operators has got back injury and related problems,
- 7women operators has got wrist problems frequently,
- 1woman has got Spinal Disk relocation serious problem.

The above problems were occurred in the indicated period but, still the problem is occurring. The design and analysis procedure in manual material handling system answers questions like:

- What types of ergonomic improvements required?
- What are the physical & physiological impacts of MMH hazards in BDTSC?
- Can MMH affect health? What are the immediate health effects of MMH?
- What are the safe manual handling techniques?

All of these questions were disseminated to workers in the section, and the responses of those questions are used in the analysis part.

The existing manual material handling systems need very strong operators. Since forces are perceived as pushes or pulls, this can provide an intuitive understanding for describing forces (Sanders and McCormik, 1987). Through experiments, it is determined (Figure 1) that the direct measurements of forces are fully consistent with the conceptual definition of force offered by Newtonian mechanics.

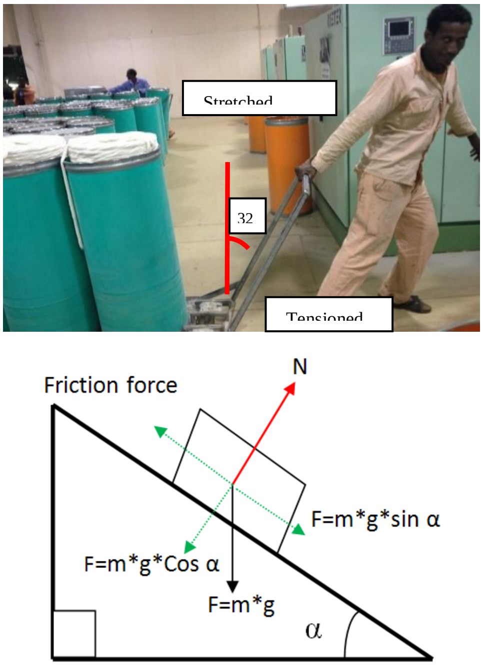

Figure 1. Existing material handling system force determination

The force exertion by the worker for the existing system is calculated based on the free body diagram analysis:

$F = \mu * m * g * \cos \alpha$ considering friction force.

Where F = the force exertion

μ = coefficient of friction= 0.8

m = mass of load pushed or pulled

g = gravity of the earth = 9.81 m/s^2

α = angle of handling = 32^o

Thus, one can has 35 kg of average load and one work content for the transportation contains 4 full slivers can with a total of 140 kg.

$F= 0.8*140 \text{ kg} *9.81 \text{ m/s}^2 * \text{Cos } 32^O$

F= $\underline{931.77 \text{ N}}$

The above tasks are almost done for 24 hours a day without break, 3 shifts of 8 hours each, equipment's, wheels and rollers are not maintained properly as shown in Figure 2. Existing wheel is shown in Figure 3.

Figure 2. Real photo for existing equipment's wheels and rollers

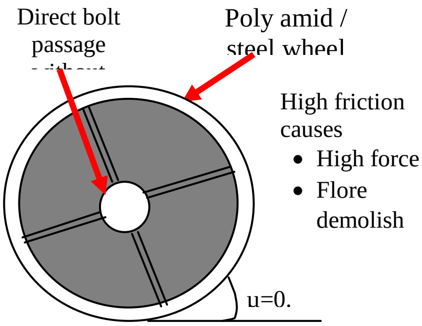

Figure 3. Existing wheel

Through interview and observations, the researchers have summarized the following.

- Problems looked when making an assessment are: the working environment, individual capacity of the operators, MMH aids and equipment, work organization factors:
- Due to improper design of MMH devices, the floor is being demolished, especially high costly NITOFLOOR EPOXY floor paint.
- Most of manual material handling aiding devices are modified or made in the workshop without considering the ergonomic aspects, nature of the work and essential devices.
- It is clear that a load may be hazardous because of: high weight of the load and awkward posture, coupling (absent or inappropriate handles, incorrect designed wheels and rollers).

The criterion selected in most biomechanical and physiological analysis of MMH design has been greatly influenced by NIOSH guidelines for Manual handling system (Revised NIOSH, 1981, 1994). Thus, NIOSH can be applied for the design of this kind of jobs.

An investigation about MMH system has to be carried out to avoid fatigues, and the analysis of all the data collected from frontline operators has been taken into account in the analysis.

4. Manual material handling system analysis with 3DSSPP software

The analysis of tasks that the researchers selected for the study is the case of spinning section: sliver can and full doffed cone transportation systems. Thus, the following report and screenshots are compiled with the help of 3DSSPP.

Step 1: Gather Information: Various measurements of the operator, sliver cans, and the posture of the operators are considered to perform the lift, push and pull. Operator's sex, height, and weight have been taken into consideration. Thus, information related to body segments has entered into the anthropometry dialog box. The operator size of 50% percentiles has taken and 26 male operators with160 cm tall and 58 kg.

Step 2: Determine the posture (Male Operator): The working posture of male operators at existing situations is shown on Fig. 4.

Figure 4. Working posture of existing male operators input analysis

Step 3: Data Analysis (male operator): The indicated posture is unacceptable posture of pushing, which will cause long term injury as show on the snapshot of software analysis (Figure 5). The average height 160.5 cm and weight 52.0 kg and the maximum coefficient of friction at the limb joints is 0.8, which is unacceptable work position.

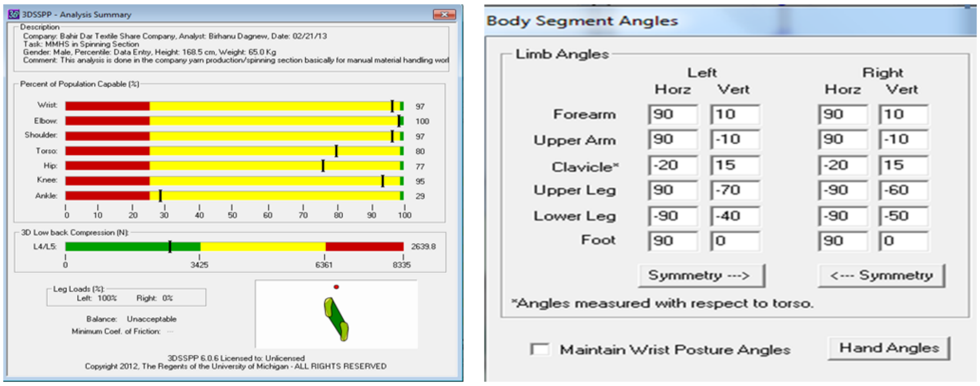

Figure 5. Existing MMH / pushing, Unacceptable posture

Determine the posture (female operator): The working posture of female operators at the existing situations is shown on the snapshot of software analysis (Figure 6).

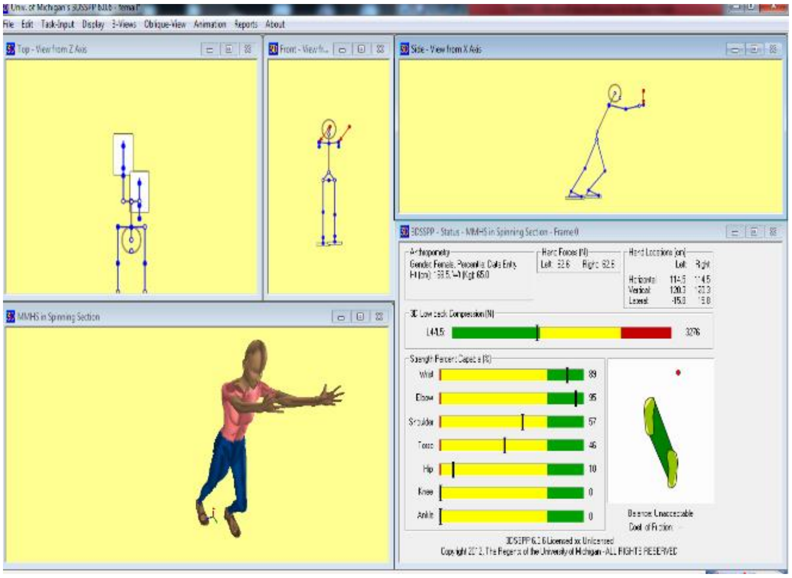

Figure 6. Working posture of existing female operators input analysis

This kind of work is very dangerous for females that it results high injury on their back and spinal lumbers. Thus, the analysis of the software indicates that it is unacceptable position of the work as shown on the Figure 7.

Average height 160.5 cm and weight 52.0 Kg and the maximum coefficient of friction at the Joints is 0.7 as indicated limb angles and it is unacceptable work position.

Figure 7. Existing manual material handling / pushing, Unacceptable posture.

Step 3 Improved postures for male operators (Figure 8).

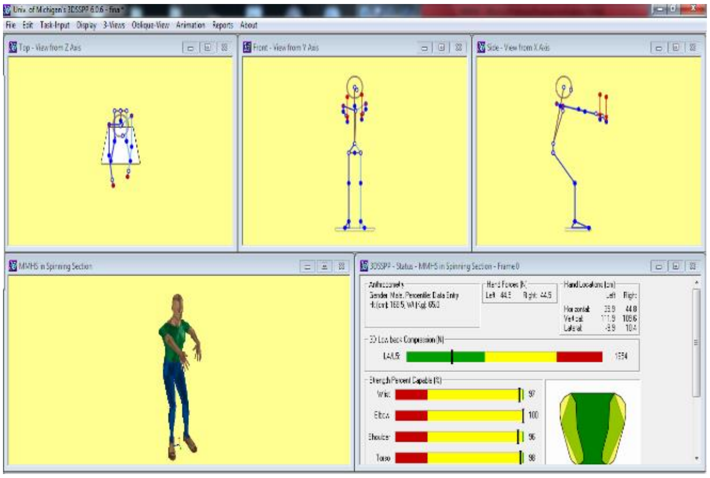

Figure 8. Improved manual material handling (pushing)

The above body segment posture in manual material handling system will not cause to injury, which is an acceptable as per the software analysis indicated Figure 9.

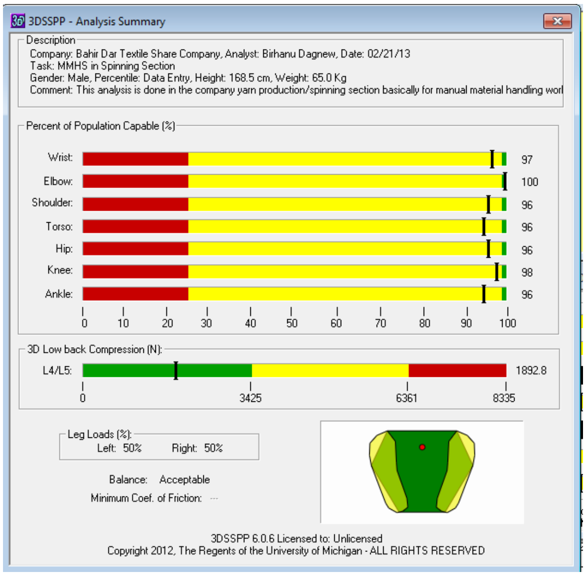

Figure 9. Software analysis for male operator posture (an acceptable posture)

Average height 160.5 cm and weight 52.0 kg and the maximum coefficient of friction at the joints are reduced to 0.5 and it is acceptable work position.

Figure 10 shows the correct type or the allowable posture of female worker as indicated and the analysis shows acceptable, which will not cause injury in the long run.

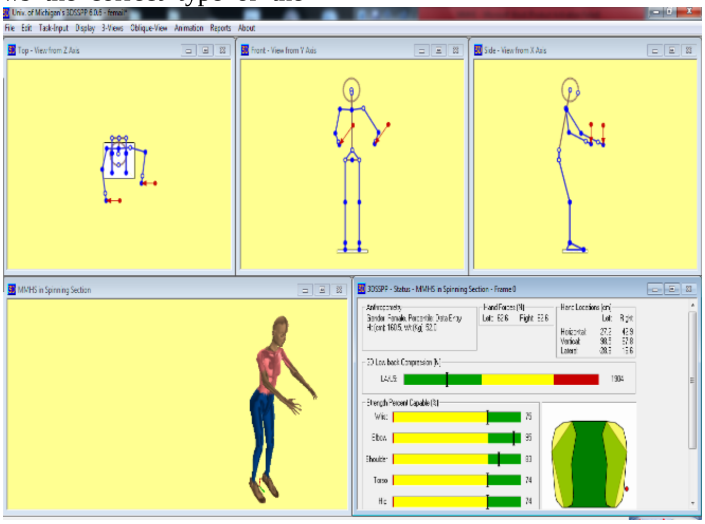

Figure 10. Improved manual material handling (pushing)

Software analysis for female operator posture is shown in Figure11.

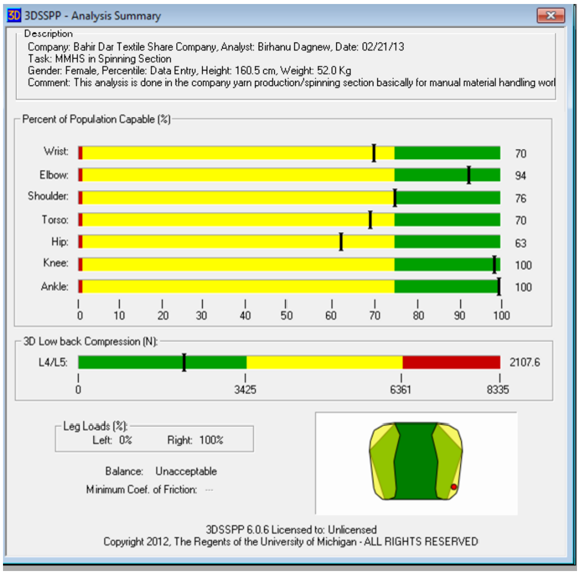

Figure 11. Software analysis for female operator posture (an acceptable posture)

Average height 160.5 cm and weight 52.0 kg and the maximum coefficient of friction at the limb and trunk joints are reduced to 0.3 as indicated limb angles and it is acceptable work position.

5. Findings of the software analysis and practical improvements

The findings of the manual material handling system design and analysis has indicated that proper manual material handling system avoided the cause of long time injuries, reduced the awkward posture of the operators, and also reduced forces required by the operators while performing their tasks.

The findings of the research also include not only the ergonomics aspects of health and safety of operators but also the cost aspect of transportation. The target is to eliminate this kind of working posture practices and improve working capability and motivation of the operators.

The researchers have identified the variables of the manual material handling system in spinning section through observation and from operators' point of view. Caster wheels and metal wheels are changed by rubber wheels, so that the manual material handling assisting devices become more comfortable, easily pushed or pulled, reduces the horizontal and vertical reaches from the origin to the lift and thus operators who are supposed to do this kind of jobs will no longer injured. The 3DSSPP software in this case helps to determine the allowable posture of workers who perform manual material handling activities. The findings are practically implemented in spinning workstations in the last four weeks (February, 2013). The improved manual material handling system has shown in Figure 12.

This change of rubber wheels and rollers results high demand of the job by the allocated operators, thus it needs easy push or pull with minimum/almost guiding force, as per the recommendation of 3DSSPP software analysis, is applied as shown in the Figure 13.

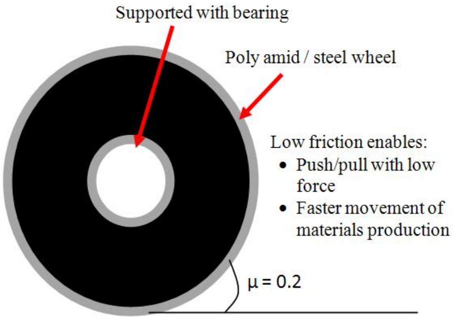

Figure 12. Improved rubber wheel's rollers

Figure 13. Small push or pull to MMH equipment for faster movement

6. Cost wise benefits

Benefits and improvements: The cost associated to this improvement has given bellow:

1. Keeping safe and increasing the service year of the costly Nito Floor Epoxy paint:
   - The epoxy investment cost = 2,188,276.00 ETB
   - Service period = 20 years minimum
   - Scratches due to existing manual material handling equipment's = 0.6%
   - Scratches reduced due to improvement =20 %

Cost savings to useful life =

$$= \frac{\text{investment cost x scratches reduction rate}}{\text{useful life x months per month}} =$$

$$= \frac{2188276 \ \text{x} \ 0.2}{20 \ \text{years x} \ 12 \ \text{years / month}}$$

2. Operators energy savings, health keeping, injury prevention:
   - Average service years of operators = 20 years
   - Monthly Salary of transporters = 1282 per month
   - Remaining working period from pension/retirement = 22 years

Cost savings to reducing health problems =

$$= \frac{\text{Monthly salary}}{\text{remaining working period x months per year}} =$$

$$= \frac{1282 \ \text{ETB/month}}{22 \ \text{years x} \ 12 \ \text{months/year}}$$

Saving = 4.84 ETB/month

3. There was a greater waiting time between Open End and Card IDF machineries to feed as an input, now after the improvement of the roller design, the speed in transportation facilities have been improved dramatically.
4. The musculoskeletal injuries due to high load pushing pulling has been eliminated that every workers will do up on their capabilities.
5. Elimination of the noise due to metal and polyamide wheels, so that the new rubber wheels and rollers do not have a noise effect in the production room any more.

   Without considering 3, 4 and 5 the total saving due to making this improvement is:
   1823.56 ETB/month+4.84 ETB/month = 1828.40 ETB/month

The force required to drive the cart with four full sliver cans is decreased and the safety of the operators as well as the floor demolishing due to friction force is decreased.

$F = \mu * m * g * \cos \alpha$ considering the friction force.
F = the force exertion
μ = coefficient of friction= 0.82
m = mass of the load pushed or pulled
g = gravity of the earth = 9.81 m/s^2
α = angle of handling = 45^o

Thus, one can has 35 kg of average load and one work content for the transportation contains 4 full slivers can with a total of 140 kg.

F= 0.2*140 kg *9.81 m/s^2 * Cos 45^O
F= 194.23 N

7. Conclusions

Manual material handling (MMH) work contributes to a large percentage of cases of musculoskeletal disorders. With the help of the 3D Static Strength Prediction Program (3DSSPP) software, MMH tasks can be designed and analyzed by considering different aspects of ergonomic principles to minimize all the musculoskeletal disorders. The research has dealt to design proper fitness between operators' physical capability and demands of the task. Proper manual material handling system avoided the cause of long time injuries, reduced the awkward posture of the operators, and also reduced forces required by the operators while performing their tasks. Therefore, the findings of the research help to improve the quality of work life of the operators in the aspects of health and safety of operators

This research has analyzed the MMH working posture of the operators using 3DSSPP software and identified major areas causing long last injury of operators due to poor ergonomics and MMH system. The research has investigated the fit between the demands of tasks and the capabilities of the operators. At the existing situations, the actual capabilities of the operators have been computed with the help of 3D Static Strength Prediction Program (3DSSPP) software and compared with the NIOSH standards. Accordingly, operators' working posture is at an unacceptable position that exposes them for musculoskeletal disorders. After the improvement of the design of the MMH device (cart's roller), the analysis has shown that the forces required by the operators to push and pull the sliver cans have been reduced from 931.77 Newton to 194.23 Newton.

8. Recommendations

Training is a very important component to back injury prevention. Workers must be educated about correct lifting techniques for the tasks they do.

Sometimes specific tasks require wearing the personal protective equipment. These may hinder movement while lifting and cause injuries.

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